Smithsonian

STC
Science and Technology Concepts™
Middle School

Earth's Dynamic Systems

Unit Sampler

Teacher Edition

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9 All-New Units for Middle School from the Smithsonian!

Smithsonian's STCMS Is Built to Meet the Next Generation Science Standards and Incorporate the 5 Innovations:

- **Three-dimensional learning** construction—every lesson, every unit
- Lessons that apply **science concepts** to NGSS* **engineering design**
- Hands-on investigations in which students build explanations for real-world **phenomena and design solutions—every day**
- **Coherent learning progression** that develops lesson by lesson, unit by unit—no "random acts of science"
- **Literacy and mathematics connections** that bridge science content and lead to deep understanding

STCMS Learning Framework

Physical Science	Life Science	Earth / Space Science
Energy, Forces, and Motion	Ecosystems and Their Interactions	Weather and Climate Systems
Matter and Its Interactions	Structure and Function	Earth's Dynamic Systems
Electricity, Waves, and Information Transfer	Genes and Molecular Machines	Space Systems Exploration

Hands Down, Research Tells Us that Inquiry-Based Instruction Is Best for Your Students

Choose instruction that has been proven to improve student performance and test scores not only in science, but also in reading and math. ◊

What students say about STC:

"In science you do hands-on activities instead of just writing and doing notes, and you get to work with people. For visual people in science that's a lot better because you get to see the experience and experiment."

What administrators say about STC:

"We saw instant results in our test scores—a double-digit increase in our end-of-grade state performance..."

◊ Visit www.carolina.com/stc to download the LASER i3 Study Results

* Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product.

Coherent Learning Progressions—Lesson by Lesson, Unit by Unit

The NGSS provide students with continued opportunities to engage in and develop a deeper understanding of the three dimensions of science. The STCMS program follows this coherent learning progression, lesson by lesson, unit by unit.

The STCMS Learning Framework—Conceptual Progression by Unit

Three units in each strand of Physical, Life, and Earth/Space Science allows you to build your middle school program

by integrated approach →

or

by strand ↓

Physical Science	Life Science	Earth/Space Science
Energy, Forces, and Motion	Ecosystems and Their Interactions	Weather and Climate Systems
Matter and Its Interactions	Structure and Function	Earth's Dynamic Systems
Electricity, Waves, and Information Transfer	Genes and Molecular Machines	Space Systems Exploration

An example of how concepts can grow across a strand within STCMS

Physical Science Concepts

Energy, Forces, and Motion develops the energy background on how visible objects move and collide resulting in energy transfer and ending with how energy can be transformed.

↓

Matter and Its Interactions builds understanding of the relationship between energy and matter and transfer and transformation at the molecular level.

↓

Electricity, Waves, and Information Transfer studies and builds an understanding of the transfer and transformation of energy, how specific energies are transmitted by waves, and the technology contributions to society that have resulted from this understanding.

Three-Dimensional Learning—The Signature Innovation of the Next Generation Science Standards

STCMS provides teacher support in weaving together Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts to address Performance Expectations over time.

Alignment to Next Generation Science Standards

- MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
- MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Lesson 6 aligns in part to the NGSS **performance expectations MS-ESS2-2 and MS-ESS3-2** by having students map seismic and volcanic activity data and also explore models of geoscience processes associated with volcanic activity and how these processes interact with Earth's surface. In Getting Started, students use what they have learned in previous lessons to **construct an explanation** of how volcanoes are formed. In Investigation 6.1, students **analyze and interpret** the similarities in seismic and volcanic activity data by overlaying plotted data from each. Students use models of geoscience processes associated with volcanic activity in Investigations 6.2 and 6.3 to see how the pressure of magma on Earth's surface can create geologic features. In Investigation 6.3, students also model GPS stations and consider how data from them can help scientists forecast future events. During Investigation 6.4, students read Building Your Knowledge: *Volcano Types* to gain information on the three major types of volcanoes and how each type changes Earth's surface in different ways. They then revisit and revise their explanations of how volcanoes are formed from the Getting Started activity.

This lesson addresses the **science and engineering practices of analyzing and interpreting data, constructing explanations and designing solutions, and developing and using models,** as well as the **crosscutting concepts of patterns, scale, proportion, and quantity, patterns, and connections to engineering, technology, and science.** In Getting Started, Investigation 6.4, and Reflecting On What You've Done, students look for patterns in the shapes of volcanoes. In Investigation 6.1, they look for patterns in two sets of data and compare the scale, proportion, and quantity of seismic and volcanic activity. Investigation 6.1 also requires students to **analyze and interpret the data** and **construct an explanation** of why volcanoes usually occur in places where there are also earthquakes. Students use two different models in Investigations 6.2 and 6.3 to gain an understanding of the influence of geoscience processes associated with volcanic activity on Earth's surface. These three investigations also have students **constructing explanations**, as they use these models to visualize how geoscience processes have created volcanoes on Earth's surface over time. In Investigation 6.3, students consider the technology used to understand the effects of volcanoes on the landscape and how the data gathered from them informs us about movements of Earth's surface.

STCMS meets the 5 Innovations of NGSS, deepening understanding of Performance Expectations

Complete Three-Dimensional Learning Support

Three-Dimensional Learning in *Earth's Dynamic Systems*:

- Ignite learning through phenomena
- Explore phenomena through experiential learning
- Use models to represent systems, develop questions and explanations, generate data, and communicate ideas
- Integrate literacy and math
- Convert learning experiences into understanding of phenomena

Alignment to the Next Generation Science Standards

Alignment to Next Generation Science Standards

Alignment of *Earth's Dynamic Systems* to Next Generation Science Standards

PERFORMANCE EXPECTATIONS

- **MS-ESS1-4.** Construct a scientific explanation based on evidence from rock strata for how the geologic timescale is used to organize Earth's 4.6-billion-year-old history.
- **MS-ESS2-1.** Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
- **MS-ESS2-2.** Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
- **MS-ESS2-3.** Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.
- **MS-ESS3-1.** Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.
- **MS-ESS3-2.** Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
- **MS-LS4-1.** Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life-forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

SCIENCE AND ENGINEERING PRACTICES

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information
- Connections to nature of science: Scientific knowledge is open to revision in light of new evidence
- Connections to nature of science: Scientific knowledge is based on empirical evidence

CROSSCUTTING CONCEPTS

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Structure and function
- Stability and change
- Connections to engineering, technology, and applications of science: influence of science, engineering, and technology on society and the natural world
- Connections to nature of science: scientific knowledge assumes an order and consistency in natural systems

DISCIPLINARY CORE IDEAS

- ESS1.C: The history of planet Earth
- ESS2.A: Earth's materials and systems
- ESS2.B: Plate tectonics and large scale system interactions
- ESS2.C: The roles of water in Earth's surface processes
- SS3.A: Natural resources
- ESS3.B: Natural hazards
- LS4.A: Evidence of common ancestry and diversity
- ETS1.A: Defining and delimiting engineering problems
- ETS1.B: Developing possible solutions
- ETS1.C: Optimizing the design solution

A Coherent Learning Progression within Each Unit

STCMS Program units develop logically and systematically to build a deep understanding of content and science and engineering practices.

From pre-assessment to summative performance assessment, students have multiple opportunities to build understanding by engaging in investigations. Within *Earth's Dynamic Systems*, students build understanding of how dynamic systems change Earth's surface.

This sampler highlights a specific group of investigations from three lessons that directly support performance expectations:

MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

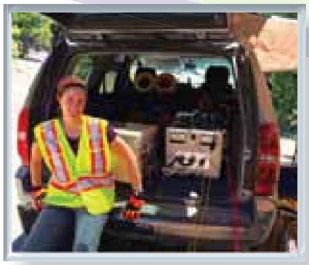
MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Three-dimensional understanding of this performance expectation builds throughout the unit. This sampler focuses on three specific opportunities: the Pre-Assessment, further investigation in Lesson 6, and the Performance Assessment in Lesson 12.

CREDIT: Margaret Baxter/© Carolina Biological Supply Company

In the **Pre-Assessment**, students are introduced to two geologic events, one of which is the 1883 eruption of Krakatau. Students examine primary source documents and images, and then describe what a data set represents and interpret similarities and differences within it.

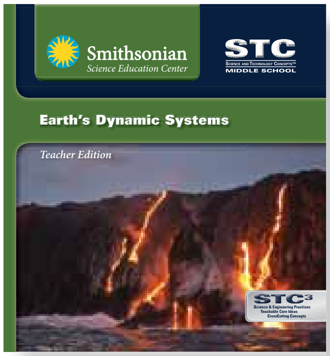
In **Lesson 6: Volcanoes: Building Up**, students gain an understanding of how volcanoes are formed, the different types of volcanoes, and the relationship between earthquakes and volcanoes. Students make the connection that volcanoes and earthquakes often occur at the same locations. Earthquakes at a volcano site can indicate potential volcanic activity. *Volcano Inflation*, a reading selection in Investigation 6.3, presents students with information about volcanologists, their equipment, and the technologies they use to monitor volcanic activity. This information allows volcanologists to provide advance warnings to people in the surrounding area.


CREDIT: U.S. Geological Survey

The information gathered in Lesson 6 directly prepares students for the **Performance Assessment in Lesson 12: Assessment: Earth's Dynamic Systems**, in which students develop their own preparedness plan for a geodynamic event. Students conduct research, use the knowledge they've gained from the unit to analyze and interpret data collected on geodynamic events, and then apply their findings to prepare a proposal for geodynamic event preparedness. Students present their proposals to the class in a panel-type presentation in which the rest of the class evaluates all preparedness plans and allocates funding for implementation based on how well the plans meet predetermined criteria.

In STCMS:

- Units average 11 lessons
- Lessons average 5–6 investigations
- Investigations are based on 45- to 50-minute sessions
- Unit completion averages 12 weeks



Details on what is included in a unit can be found on the back cover of this sampler.

Coherent Learning Progression—Lesson by Lesson

Concept Storyline

A systematic approach builds deep three-dimensional understanding

Earth's Dynamic Systems Concept Storyline

Unit Driving Question: How do the dynamic systems of Earth change its surface?

Lesson 1: *Pre-Assessment: Earth's Dynamic Systems*

Focus Question: What do you know about geologic processes?

Students are introduced to two geologic events, the eruption of Krakatau in 1883 and the discovery of the Burgess Shale in 1909, through primary source documents and images. They consider these events, predict the way they may have occurred, and develop questions to explore about these events during the unit.

Lesson 2: *When the Earth Shakes*

Focus Question: Why are some structures damaged when Earth shakes?

Students observe videos of earthquakes and are introduced to shake tables as a way to model earthquakes. They design and conduct an experiment to investigate the effect of design variables on the way model buildings respond to shaking. Students use experimental data to describe conditions for areas with the greatest and least risk for future earthquake damage. Students then use iterative testing and modification to design a model of an earthquake-resistant house.

Lesson 3: *Analyzing Earthquake Data*

Focus Question: How can we collect data about earthquakes?

Students explore how data pertaining to earthquakes can be collected and analyzed. They explore wave motion, use model seismographs to collect simulated earthquake data, analyze seismogram readings, and use earthquake data to locate the epicenter of a quake. Through these investigations, students come to understand how earthquake data can show patterns that help in the prediction of future quakes.

Lesson 4: *Investigating Plate Movement*

Focus Question: How do changes in the lithosphere affect Earth's surface?

Students plot earthquake data to investigate patterns caused by earthquakes. They also examine the structure of Earth's interior to gain an understanding of the dynamic nature of Earth. Using models, students also simulate the movement of tectonic plates and examine the cause and effect of plate movements along faults.

Lesson 5: *Cycling Matter and Energy*

Focus Question: How do heat and pressure impact geologic features?

Students model the rock cycle and investigate the role of heat and pressure in cycling matter and energy. They also examine rock samples and use observational data to engage in an argument from evidence about the formation of each sample.

Lesson 6: *Volcanoes: Building Up*

Focus Question: How are volcanoes formed?

Students gain an understanding of how volcanoes are formed by modeling the movement of magma through Earth's surface. They then examine information pertaining to different types of volcanoes and gain an understanding of the relationship between earthquakes and volcanoes.

Lesson 7: *Volcanoes: Eruption*

Focus Question: How do volcanoes change Earth's surface?

Students conduct investigations to gain an understanding of how volcanoes contribute to the modification and creation of landforms. Students then revisit the Krakatau event and construct an explanation for the phenomenon, which involves changes at Earth's surface. Students make predictions for how surface features will continue to change in the future as geoscience processes continue to occur.

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Lesson 8: *Changing Earth's Surface*

Focus Question: How have geoscience processes changed Earth's surface?

Students model several different geoscience processes to gain an understanding of their effect on Earth's surface. They research a real-world example of a process they modeled and present their findings. Students then revisit the Burgess Shale event and construct an explanation for rock deformation.

Lesson 9: *Analyzing the Fossil Record*

Focus Question: What do fossils and layers of sediment tell us about Earth's past?

Students investigate how fossils are formed and what they can tell us about the planet's history and the organisms that they represent. Through modeling and simulations, students examine the role of fossils in explaining the geologic events of the past. Students also use fossils to analyze and interpret patterns related to existence, diversity, anatomical structures, and extinction of organisms.

Lesson 10: *Distribution of Resources on Earth*

Focus Question: How do geoscience processes impact the distribution of resources on Earth?

Students map the locations of a specific mineral resource to reveal its uneven distribution and construct a scientific explanation. They use a model to simulate drilling for a natural resource and calculate the cost of the simulated exploration. Students also conduct research related to the mineral, energy, and groundwater resources of Earth and present their findings to the class.

Lesson 11: *Evidence of a Dynamic Earth*

Focus Question: What evidence suggests that Earth is a dynamic geological system?

Students again revisit Burgess Shale fossils and construct an explanation for an aquatic fossil being found well above sea level. Students will describe an appropriate timescale for the time since the fossil was underwater and the rate of elevation increase. Students will also analyze and interpret data related to the distribution of fossils and rocks, continental landforms, and features on the seafloor as evidence for plate motion in Earth's past.

Lesson 12: *Assessment: Earth's Dynamic Systems*

Focus Question: How can we use knowledge of Earth's dynamic systems to understand the past and prepare for the future?

The unit concludes with a two-part assessment. The first part is a Performance Assessment, in which students, acting as scientists, prepare and present proposals for mitigating the effects of future geodynamic events. Students also evaluate proposals from other groups and make recommendations for which proposals should receive funds. In the second part, students complete a Written Assessment that covers the performance expectations, disciplinary core ideas, crosscutting concepts, and science and engineering practices addressed in this unit.

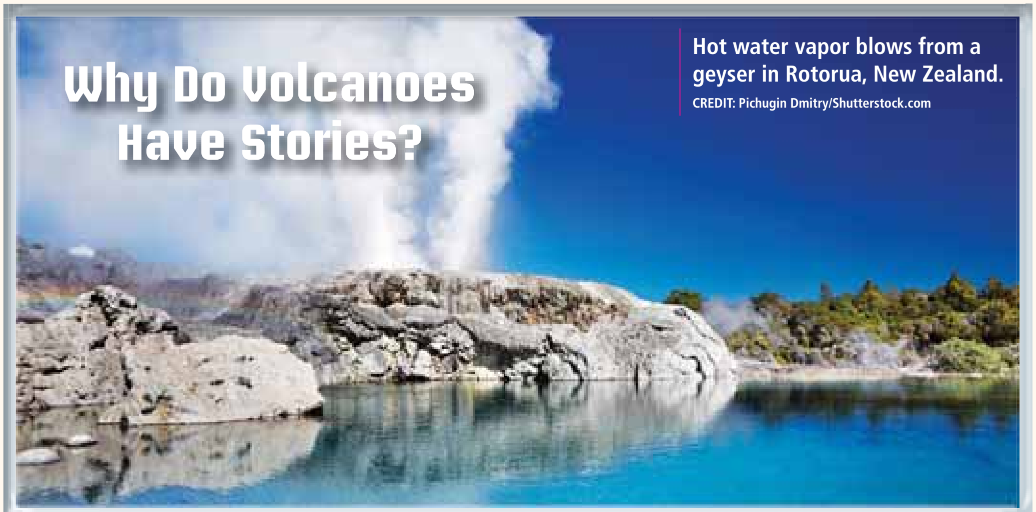
More resources for teachers and students found at:
www.carolinascienceonline.com
www.ssec.si.edu/STCMS

Non-Fiction Literacy Connected to Science Phenomena

Non-fiction literacy selections introduce students to phenomena and support their experiential learning, deepening their understanding.

Introduce science phenomena through non-fiction Literacy

BUILDING YOUR KNOWLEDGE — *READING SELECTION*



Hot water vapor blows from a geyser in Rotorua, New Zealand.
CREDIT: Pichugin Dmitry/Shutterstock.com

New Zealand, a large island country in the southwestern Pacific Ocean near Australia, is almost always blowing off steam. If volcanoes are not exploding, then hot springs, geysers, and boiling lakes are active. When the British came to explore New Zealand, they found indigenous people called the Maori living there.

The Maori have many myths and legends that they tell to share their culture and to explain natural phenomena. One Maori tale, "How Volcanoes Got Their Fire," tells how fire came to volcanoes in New Zealand. In another tale, "Battle of the Giants," volcanoes act like giant people.

A Maori king from the early 1900s
CREDIT: Library of Congress, Prints & Photographs Division, LC-USZ62-109768

How Volcanoes Got Their Fire

A powerful medicine man named Ngatoro led his people from Hawaii to New Zealand in canoes. After they arrived, Ngatoro took his female slave, Auruhoe, and climbed the volcano Tongariro. He asked the rest of his people to stop eating until he and Auruhoe returned. He believed this would give him strength against the cold air high on the mountain. Ngatoro and his slave stayed longer than expected. His people got hungry and began eating again. When that happened, Ngatoro and Auruhoe felt the freezing cold. Ngatoro prayed to his sisters back in Hawaii to send fire to warm them. The sisters heard his cry for help and called up fire demons who began to swim underwater toward New Zealand. When the fire demons came up at White Island to find out where they were, the earth burst into flames. The demons reached the mainland and continued to travel underground toward

continued

ELA Connection
RST.6-8.9
WHST.6-8.2

Tongariro. Wherever the fire demons surfaced, hot water spewed from the earth and formed a hot spring or geyser. Finally, the fire demons burst out of the top of Tongariro. Their fire warmed Ngatoro and helped save his life, but Auruhoe was already dead from the cold. To remember the journey of Ngatoro and Auruhoe, the Maori called the mountain Ngauruhoe.

Battle of the Giants

Three volcanoes—Taranaki, Ruapehu, and Tongariro—lived near each other. Taranaki and Ruapehu both fell in love with Tongariro, but she could not decide which one she preferred. Finally, they decided to fight for her. Tearing himself loose from the earth, Taranaki thrust himself at Ruapehu and tried to crush him. "I'll get you," fumed Ruapehu. He heated the waters in his crater lake until they were boiling. Then he sprayed scalding water over Taranaki and on the countryside around him. The scalding bath hurt Taranaki badly. Furious, he hurled a shower of stones at Ruapehu. The stones broke the top of Ruapehu's cone, which ruined his good looks. "I'll show him," said Ruapehu. He swallowed his broken cone, melted it, and spat it at Taranaki. The molten cone burned Taranaki badly, and he ran to the sea to cool his burns. ■

Discussion Questions

1. Why do you think the Maori people tell stories like "How Volcanoes Got Their Fire"?
2. How do nonscientific stories differ from scientific explanations?
3. What sorts of geologic processes might the Maori people have been describing in the telling of "Battle of the Giants"?

According to the legend, Mount Ruapehu's broken top was caused by the stones that the volcano Taranaki hurled at it.

CREDIT: Pi-Lens/Shutterstock.com

Mount Ngauruhoe is located on the North Island of New Zealand.

CREDIT: TrashTheLens/Shutterstock.com

What Do They Already Know?

Pre-assessment investigations help teachers gain insight into students' prior knowledge and misconceptions. Pre-assessments introduce students to science phenomena they will investigate throughout the unit, beginning the construction of deep understanding and the ability to explain phenomena.

Investigation 1.1: Krakatau, 1883 asks students to describe what a data set represents and to interpret similarities and differences within the data set as they relate to seismic activity. Students use this evidence to consider if these events are related to one another.

Lesson 1

Pre-Assessment: Earth's Dynamic Systems

Investigation 1.1: Krakatau, 1883

Procedure

1. Inform students that in 1883, large-scale geologic events took place on the Indonesian island of Krakatau, which is sometimes referred to by its English name, Krakatoa. These events had a significant impact on the island itself and far beyond it. In fact, the sound from the eruptions was heard in other parts of the world.

2. Divide students into groups. Students will use Student Guide Figure 1.3 to locate many of the places named in this investigation. Explain that knowing where these locations are in relation to one another may help understand events described in the Krakatau Card Set.

3. Have students spend a few minutes reading and examining each card in the Krakatau Card Set. The cards can be distributed among students in the group, and when one student has finished with a card, he or she can pass it to another student in the group. Students should consider how they described the term "phenomena" in Getting Started and select a card they think represents a good example. Facilitate students sharing their examples with the class. As needed, refer students back to their working definition (similar to "an observed event that can be scientifically explained [or predicted]"). Student examples should reflect their understanding that phenomena are events that were experienced and documented.

4. Give students approximately 10 minutes to read and examine the cards in the Krakatau Card Set. The cards are intended to pique student interest about the historic event and generate scientifically relevant questions. Some of the questions students generate may be questions that they investigate during the unit or questions that they will answer after they have gained the necessary knowledge. Students should write down any questions or ideas they have in their science notebooks. Move around the room, keeping students on track and helping them hone questions that can be discussed with the group. Give students a warning when they have 2 minutes left to read and examine the cards.

Investigation 1.1

Krakatau, 1883

Materials

For you
- Science notebook

For your group
- 1 Krakatau Card Set

Procedure

1. Krakatau (Figure 1.1) is sometimes referred to using its English name, Krakatoa. In 1883, people all over Indonesia and around the world observed phenomena related to events happening on Krakatau. The Krakatau Card Set includes some observations and illustrations of the phenomena.
2. The Krakatau Card Set describes several locations near the island. Use Figure 1.3 to locate the following:
   - **a.** Anjer
   - **b.** Bantam (now Banten)
   - **c.** Batavia (now Jakarta)
   - **d.** First Point
   - **e.** Java
   - **f.** Krakatau
   - **g.** Merak
   - **h.** Sunda Strait
   - **i.** Sumatra
   - **j.** Tyringen
3. Read or examine each card in the Krakatau Card Set. Think about how you described the term "phenomena" during Getting Started. Select one card that you think represents a good example of a phenomenon. Record your example in your science notebook and explain why you think it is a good example of a phenomenon. Be prepared to share your example with the class.
4. Continue reading and examining each card in the Krakatau Card Set. In your science notebook, record any questions you have about the phenomena. Discuss these questions with your group.
5. Discuss where you think the island went and why the events that were happening made people record the observations and illustrations they did. Record your group's responses in your science notebook.
6. In your science notebook, explain what you think happened on Krakatau in 1883. Support your explanation using your prior knowledge and evidence from the card set. (**Note:** You may wish to organize your explanations using events that occurred before, during, and after what occurred in 1883.)
7. Between 1880 and 1884, many seismic events occurred in Indonesia near Krakatau. A summary of these events is shown in Table 1.1. Read through the descriptions of each seismic event. In your science notebook, record any questions you have about the phenomena.

Figure 1.3
Map of Java and Sumatra
CREDIT: Margaret Baxter/© Carolina Biological Supply Company

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5. After about 10 minutes, have groups discuss the questions each student wrote in their notebooks. Give students a few minutes for this, and then have them discuss where they think the island went and why people recorded the observations and illustrations that they did when the event was happening. You may wish to have students take notes during the discussion in their science notebooks. While students discuss their ideas, walk around the room and listen for what students already know and any misconceptions they may have.

6. Students should write an explanation of what they think happened on Krakatau in 1883. Student explanations should be supported by their prior knowledge about volcanic eruptions (from personal experiences or information learned in previous grades), as well as any evidence they find in the card set. While students work, circulate around the room to ensure that students are using the cards appropriately and sharing them within their group. Allow about 5 minutes for students to record their explanations in their science notebooks.

7. Direct students to look at Student Guide Table 1.1 and read through each of the events. Students should use their science notebooks to record any questions they have about the phenomena and events described in the table.

continued

ELA Connection
RST.6-8.7

Table 1.1. Seismic Events Occurring Near Krakatau

Date	Time	Remarks (with distance and direction of cities from Krakatau noted)
Sept. 1, 1880	4:35 p.m.	Several earthquakes, largest with epicenter in Bantam (155 km E) felt as far as northern Australia; the lighthouse on Java's First Point (74 km SSE) is damaged.
Mar. 10, 1882	4:57 p.m.	Earthquake with epicenter in Pekalongen (485 km E); felt in Bantam (155 km E).
May 9–10, 1883		Earthquakes felt at Java's First Point lighthouse (74 km SSE).
May 15–20, 1883		Earthquakes felt at Ketimbang (40 km NNE).
May 17, 1883	10:25 a.m.	Light tremor felt at Anjer (55 km E).
May 27, 1883	2:00 a.m. 3:55 a.m.	Two shocks felt at Tyringen; last also felt in Pandeglang (74 km E × N).
May 27, 1883	3:30 a.m. 4:20 a.m.	Earthquake ("horizontal shock") felt at Teluk Betong (80 km NNW) lasts 15 sec. Three "heavy jolts" are felt at 3:30 and 4:20 a.m. at lighthouse on Java's First Point (74 km SSE).
May 27, 1883	4:00 a.m. 4:30 a.m.	Two shocks are felt at Valakke Hoek lighthouse (75 km SSW).
May 31, 1883		During night of May 31–June 1, hopper *Bintaing* is "suddenly rocked" in water while anchored at Blinjoe (500 km NE).
July, 1883		Earthquakes felt in Java.
Aug. 26, 1883	7:30 p.m.	Six earthquake shocks felt during the night.
Aug. 26, 1883	7:50 p.m.	Severe earthquakes reported at Java's First Point lighthouse (74 km SSE).
Aug. 26, 1883	8:30 p.m.	Violent eruptions occur on Krakatau; strong ground shaking felt in Anjer (55 km E).
Aug. 27, 1883	2:00 a.m. 3:00 a.m.	Two earthquakes reported at Anjer (55 km E), believed to be air wave effects from eruption.
Aug. 27, 1883	1:30 a.m. 3:00 a.m. 4:00 a.m.	Three earthquakes reported at Java's First Point lighthouse (74 km SSE), believed to be air wave effects from eruption.
Sept. 1, 1883	3:45 a.m. 4:30 a.m.	Earthquakes felt at Menes (56 km SSE).
Sept. 1, 1883	4:00 a.m.	Earthquake felt at Tjimanoek (72 km SSE), 2 tremors.
Sept. 14–15, 1883		Four earthquakes felt in Padang (800 km NW) during the night.
Sept. 18, 1883	12:45 p.m. 1:00 p.m.	First earthquake felt at Ranjkas Betong (Bantam), second recorded at 1:00 p.m. at Malimping (Bantam) and Java's First Point lighthouse (74 km SSE).
Sept. 26, 1883		Detonations [from Krakatau] were distinctly heard, and tremors of the ground were reported [in Penang].
Dec. 6, 1883	7:30 p.m.	An earthquake is felt over a large part of Bantam (155 km E).
Jan–Feb. 1884		Earthquakes are felt at the Vlakke Hock lighthouse (75 km SSW).
Feb. 23, 1884		Near Batavia (160 km E), ground tremors, rattling of doors and windows, and a red glow in the west observed in the evening.
Dec. 6, 1884	7:03 p.m.	Earthquake felt over most of Bantam (155 km E).

SOURCE: Simkin, T., & Fiske, R. S. (1983). *Krakatau, 1883—The volcanic eruption and its effects.* Washington, DC: Smithsonian Institution Press.

continued

Use pre-assessments to introduce phenomena and identify misconceptions early on

NGSS, English Language Arts, and Math Standards

Lesson at a Glance provides an overview of each lesson, including lesson-specific correlations to the NGSS and connections to English Language Arts and Math Standards.

Lesson 6 Volcanoes: Building Up

	GETTING STARTED	INVESTIGATION 6.1: Comparing Volcanic and Seismic Activity	INVESTIGATION 6.2: Investigating Magma and New Landforms	INVESTIGATION 6.3: Volcano Monitoring
Overview	• Students brainstorm what they know about tectonic processes and apply that knowledge to design a concept map of how volcanoes form. • Students categorize a set of volcano cards based on characteristics they observe in the volcano photos.	• Students plot and analyze data about earthquakes and volcanic eruptions. • Students construct an explanation for the relationship between the two types of geological events. • Students read Building Your Knowledge: *Earthquake Swarms* to learn about patterns scientists use to differentiate swarms associated with volcanoes from those along faults.	• Students use a model to explore how magma below Earth's surface can affect the shape of the land above it.	• Students construct a model to investigate changes in Earth's surface as pressure from magma builds up in the magma chamber of a volcano prior to an eruption. • Students read Building Your Knowledge: *Volcano Inflation* to gain an understanding of the technology volcanologists use to monitor changes in Earth's surface to help predict eruptions. • Students compare and contrast their model to actual volcano inflation and monitoring.
Objectives	• Observe patterns in the shapes of volcanoes and use those observations to categorize volcanoes into groups.	• Analyze and interpret data on volcanoes and earthquakes and use that analysis to forecast future events.	• Use models to understand how geological events change Earth's surface at varying time and spatial scales.	• Use models to understand how geological events change Earth's surface at varying time and spatial scales. • Understand how scientists use patterns in data to predict volcanic eruptions. • Understand how new technology and engineering can help scientists observe patterns in geologic activity.
Concepts	• Volcanoes vary in size, shape, and location around the world.	• Seismic activity can be predictive of volcanic activity.	• Magma and lava can change the appearance of landforms.	• Volcano inflation is a geoscience process that can influence the surface features of Earth. • Scientists use different types of technology to monitor volcano inflation and predict volcanic activity.
Assessment	Pre-Assessment	Formative	Formative	Formative
Key Terms	Landform Latitude Longitude Magma Volcano	Earthquake Earthquake swarm Magnitude Seismic station Seismogram	Landform Lava Magma	Seismometer Tiltmeter Volcano inflation
Time	0.5 period	0.5 period	1 period	1 period

Standards

ALIGNMENT TO NEXT GENERATION SCIENCE STANDARDS

Performance Expectations
- MS-ESS2-2
- MS-ESS3-2

Science and Engineering Practices
- Analyzing and interpreting data
- Developing and using models
- Constructing explanations and designing solutions

Crosscutting Concepts
- Patterns
- Scale, proportion, and quantity
- Connections to engineering, technology, and science

Disciplinary Core Ideas
- ESS2.A: Earth's materials and systems
- ESS3.B: Natural hazards

Daily NGSS support

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LESSON AT A GLANCE

	INVESTIGATION 6.4: Volcano Types	**REFLECTING ON WHAT YOU'VE DONE**	***EXTENDING YOUR KNOWLEDGE*** **READING SELECTIONS**
	• Students read Building Your Knowledge: *Volcano Types* to gain more information about the three major types of volcanoes. • Students revisit the volcano cards they used during Getting Started and re-sort them based on the information they have gained throughout the lesson.	• Students review what they have learned about how the shape of a volcano gives clues about its type. • Students consider the influence of lava on the type and shape of a volcano. • Students devise a strategy to determine whether a volcano is active. • Students revisit and update their concept maps based on new information gained.	• *Volcanoes: Help or Hindrance?* explores the positive and negative impacts of volcanic eruptions on human life and the larger environment. • *Reading the Signs: Detecting Seismic Events* describes how systems are engineered to detect patterns, scale, and quantity of seismic events to help forecast catastrophic events. • *An Island Is Born* explains how volcanic activity led to the creation of the island of Surtsey in 1963. • *Smithsonian Global Volcanism Program* covers the research, archiving, and outreach missions of the GVP.
	• Observe patterns in the shape of volcanoes and use those observations to categorize volcanoes into groups.	• Review new knowledge about how the shape of a volcano gives clues about its type. • Consider the influence of fault type and lava characteristics on the shape and type of a volcano. • Devise a strategy for determining whether a volcano is active. • Revise the concept map on geoscience processes that result in volcano formation based on new knowledge gained.	• ***Volcanoes: Help or Hindrance?*** Understand that while volcanoes are destructive in a number of ways, they also provide benefits, such as natural resources, soil nutrients, enjoyable landscapes, and hot springs. • ***Reading the Signs: Detecting Seismic Events*** Learn about early warning systems for tsunamis. Understand that while we are still unable to predict volcanic eruptions, by monitoring warning signs, geologists can get a sense for the probability that an eruption will occur. • ***An Island Is Born*** Learn the story of the eruption of an underwater volcano in 1963 that allowed scientists to observe the formation of a new island. • ***Smithsonian Global Volcanism Program*** Get insight into the scientific importance of the Smithsonian's program, which observes and archives volcanic activity around the globe and educates the public about volcanoes.
	• Volcanoes can be categorized based on shape, which is influenced by the characteristics of the lava flowing out of a particular volcano.	• The formation and type of volcanoes are determined by geologic events on Earth's surface. • Seismic activity aids in the prediction of volcanic activity. • Technology used in monitoring geoscience processes aids in the prediction of volcanic activity.	• Volcanic activity can have both destructive and constructive results. • Technology can be used to monitor seismic activity and decrease the catastrophic effects of seismic activity on humans. • Islands can form due to volcanic activity over different periods of time. • The Smithsonian's Global Volcanism Program provides a depository for volcanic activity data and continued research to understand and monitor volcanic activity.
	Formative	Formative	
	Cinder cone volcano Composite volcano Fissure Hot spot Shield volcano Vent	Viscosity	Crust Lahar Mantle Mineral Petrology Tsunami
	1 period	1 period	

Daily ELA and math support

CONNECTIONS

English Language Arts

- RST.6-8.1 Key idea and details
- RST.6-8.3 Key idea and details
- RST.6-8.7 Integration of knowledge and ideas
- RST.6-8.10 Range of reading and level of text complexity
- SL.6-8.1 Comprehension and collaboration
- SL 6-8.5 Presentation of knowledge and ideas
- WHST.6-12.9 Research to build and present knowledge

Mathematics

- MP3 Construct viable arguments and critique the reasoning of others

Support for Teachers During the Transition to NGSS

Lesson-specific alignment to NGSS makes it clear how each part of the standards is tackled, ensuring true three-dimensional learning.

Lesson-specific correlations tell you the what and how of NGSS—in every lesson

Lesson 6

Volcanoes: Building Up

circular or oval cone. Cinders are pebble-sized rock fragments that have the same composition as ash. They are glassy and contain numerous bubbles created by the gas that escaped as the magma exploded into the air and then cooled quickly. Cinder cones range in size from 10 to 400 m high.

Cinder cones are commonly found on the sides of shield volcanoes, composite volcanoes, and calderas. For example, geologists have identified nearly 100 cinder cones on the flanks of Mauna Kea, a shield volcano on the island of Hawaii. Most cinder cones have a bowl-shaped crater at the summit, from which cinders are ejected. Lava rarely issues from the top because the loose, uncemented cinders are too weak to support the pressure exerted by molten rock as it rises toward the surface through the central vent. Therefore, cinder cones usually erupt their lava flows from the base of the cone.

Alignment to Next Generation Science Standards

- MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.
- MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Lesson 6 aligns in part to the NGSS **performance expectations MS-ESS2-2 and MS-ESS3-2** by having students map seismic and volcanic activity data and also explore models of geoscience processes associated with volcanic activity and how these processes interact with Earth's surface. In Getting Started, students use what they have learned in previous lessons to **construct an explanation** of how volcanoes are formed. In Investigation 6.1, students **analyze and interpret** the similarities in seismic and volcanic activity data by overlaying plotted data from each. Students use models of geoscience processes associated with volcanic activity in Investigations 6.2 and 6.3 to see how the pressure of magma on Earth's surface can create geologic features. In Investigation 6.3, students also model GPS stations and consider how data from them can help scientists forecast future events. During Investigation 6.4, students read Building Your Knowledge: *Volcano Types* to gain information on the three major types of volcanoes and how each type changes Earth's surface in different ways. They then revisit and revise their explanations of how volcanoes are formed from the Getting Started activity.

This lesson addresses the **science and engineering practices of analyzing and interpreting data, constructing explanations and designing solutions, and developing and using models,** as well as the **crosscutting concepts of patterns, scale, proportion, and quantity, patterns, and connections to engineering, technology, and science.** In Getting Started, Investigation 6.4, and Reflecting On What You've Done, students look for patterns in the shapes of volcanoes. In Investigation 6.1, they look for patterns in two sets of data and compare the scale, proportion, and quantity of seismic and volcanic activity. Investigation 6.1 also requires students to **analyze and interpret the data** and **construct an explanation** of why volcanoes usually occur in places where there are also earthquakes. Students use two different models in Investigations 6.2 and 6.3 to gain an understanding of the influence of geoscience processes associated with volcanic activity on Earth's surface. These three investigations also have students **constructing explanations**, as they use these models to visualize how geoscience processes have created volcanoes on Earth's surface over time. In Investigation 6.3, students consider the technology used to understand the effects of volcanoes on the landscape and how the data gathered from them informs us about movements of Earth's surface.

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Building Coherent Learning Progressions within a Lesson

Through a series of investigations in Lesson 6: Volcanoes: Building Up, students build an understanding of how volcanos are formed, the different types of volcanoes, and the relationship between earthquakes and volcanoes.

Lesson 6 **Volcanoes: Building Up**

CONNECTIONS

English Language Arts

Getting Started
Investigation 6.1
Investigation 6.2
Investigation 6.3
Investigation 6.4
Reflecting On What You've Done

Science Notebook

Getting Started
Investigation 6.1
Investigation 6.2
Investigation 6.3
Investigation 6.4
Reflecting On What You've Done

Lesson 6 Volcanoes: Building Up

FOCUS QUESTION How are volcanoes formed?

Introduction

In 2010, the Icelandic volcano Eyjafjallajökull began an eruption that lasted six months. In its first days, the eruption sent so many tons of ash into the sky that 20 nearby countries halted air travel. We often think of volcanoes as spewing towers of red-hot lava. But when volcanoes like Eyjafjallajökull erupt, magma flows out slowly, and lighter ash material is expelled with force. In this lesson, you will map historic volcano data and analyze how it relates to earthquakes. You will also use models to see how the movement of magma in a volcano shapes the surface of Earth, sometimes over thousands of years and sometimes very quickly. By the end of the lesson, you will use evidence to explain factors that contribute to the formation of different volcano types and how scientists can predict their activity.

Figure 6.1
Does this picture match the image that usually comes to mind when you think of a volcano? Where do you think the ash erupting from Eyjafjallajökull is coming from?
CREDIT: J. Helgason/Shutterstock.com

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A Systematic Approach to Building Understanding of Content and Science and Engineering Practices

Investigation 6.1: Students gain an understanding of the relationship between earthquakes and volcanoes. Students make the connection that volcanoes and earthquakes often occur at the same locations.

Investigation 6.1

Comparing Volcanic and Seismic Activity

Materials

For you

- Science notebook

For your group

- 2 Lesson Master 6.1a: *Plotting Volcanic and Seismic Activity*
- 1 Lesson Master 6.1b: *Volcanic Activity*
- 1 Lesson Master 6.1c: *Seismic Activity*
- 2 Transparency sheets
- 2 Wet-erase markers
- Masking tape

Procedure

1. In this investigation, you will use a map to plot volcanic and seismic activity and compare patterns. Use a piece of tape to attach a transparency sheet to each copy of Lesson Master 6.1a: *Plotting Volcanic and Seismic Activity*.
2. Divide your group into pairs. One pair will use Lesson Master 6.1b: *Volcanic Activity* to plot coordinates on Lesson Master 6.1a. The other pair will use Lesson Master 6.1c: *Seismic Activity* to plot coordinates on Lesson Master 6.1a.
3. Each pair should choose one marker from the set to plot the coordinates from their lesson master on their transparency.
4. When both pairs are done plotting, separate the transparency with the seismic activity data plotted on it from the map and place it over the transparency of the volcanic activity data. (Keep the volcanic activity transparency taped to the map.) As a group, discuss the following questions and record your answers in your science notebook. Be prepared to share your answers with the class.
   a. What patterns do you see in the locations of seismic activity and volcanic activity?
   b. How do you explain these patterns?
   c. Think back to Investigation 4.1, in which you plotted seismic activity. What predictions can you make concerning seismic activity, volcanic activity, and plate boundaries?
5. Your teacher will show you a projection of a much more complete set of volcano data paired with earthquake data. As a group, discuss how this additional information supports your explanations for the questions in Step 4. Make any modifications to your responses that seem appropriate, and then share your answers with the class.
6. Read Building Your Knowledge: *Earthquake Swarms*. Then, answer the questions below in your science notebook:
   a. Why do scientists pay attention to a pattern of many small earthquakes in a small area over a short period of time?
   b. What are two things that can cause earthquake swarms, and how are the swarms they produce different?

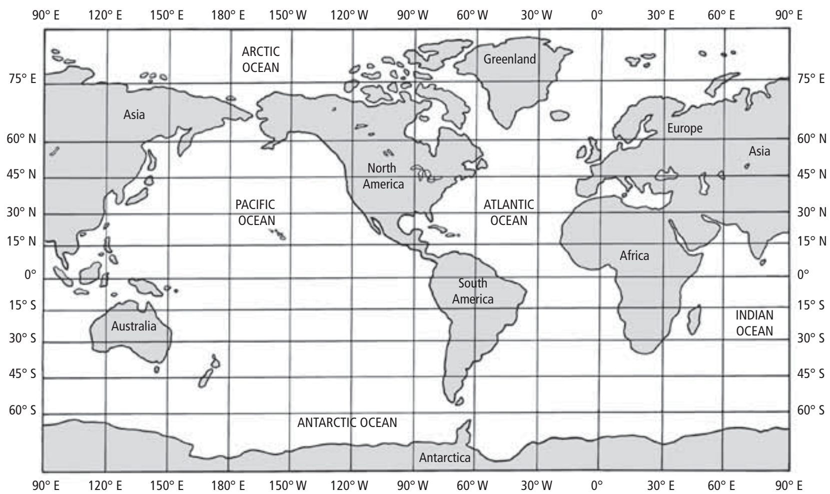
EXIT SLIP

Explain the relationship between earthquakes and volcanoes.

Lesson 6

ELA Connection RST.6-8.1, 7

Lesson Master 6.1a: Plotting Volcanic and Seismic Activity



STCMS™ / Earth's Dynamic Systems   Lesson 6 / Volcanoes: Building Up

Analyzing and interpreting data to make predictions

Lesson Master 6.1c: Seismic Activity

Earthquake Number	Latitude	Longitude
1	28° N	129° E
2	7° N	127° E
3	36° N	129° E
4	40° N	126° W
5	43° N	13° E
6	1° N	80° W
7	26° N	120° E
8	33° N	133° E
9	6.3° S	130° E
10	19° N	107° W
11	25° S	21° W
12	64° N	21° W
13	14° N	121° E
14	32° S	72° W
15	3° S	139° E
16	36° S	74° W
17	40° N	143° E
18	5° N	83° W
19	61° N	148° W
20	43° N	13° W

STCMS™ / Earth's Dynamic Systems   Lesson 6 / Volcanoes: Building Up

Lesson Master 6.1b: Volcanic Activity

Volcano Number	Latitude	Longitude
1	41° N	122° W
2	41° N	14° W
3	13° N	124° E
4	25° S	69° W
5	0° S	78° W
6	16° S	72° W
7	57° N	158° W
8	38° N	15° E
9	6° S	130° E
10	35° N	138° E
11	63° N	19° W
12	46° N	122° W
13	38° N	131° E
14	37° N	138° W
15	0°	126° E
16	71° N	8° W
17	2° S	121° E
18	33° N	127° E
19	1° N	125° E
20	8° S	118° E

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Investigation 6.2

Investigating Magma and New Landforms

Materials

For you

- Science notebook
- Safety goggles

For your group

- 2 Containers of Model Magma™ (1 heated, 1 room temperature)
- 2 Containers of soil
- 1 Plastic box
- 1 Plastic container with lid (no hole in the base)
- 1 Plastic spoon

Safety Warnings

- **Be careful when handling the heated Model Magma.**
- **Heated Model Magma should always be observed and investigated inside the plastic box to avoid dangerous situations that could result from spillage.**
- **If pouring Model Magma into your containers, use a beaker clamp, as shown in Figure 6.3.**
- **Fill your beaker in the area where the hot pots are set up. Do not remove the hot beaker from that area.**

Procedure

1. In the next two investigations, you will explore how magma and lava can affect the shape of Earth's surface. You will observe two containers of Model Magma: one container with room-temperature Model Magma and one with heated Model Magma. Review the safety warnings about working with Model Magma, and then follow your teacher's instructions to obtain the samples. Look closely at each sample. In your science notebook, describe its properties and consider the following:
   a. What type of matter do you think this substance is? Give two reasons to support your answer.
   b. Predict whether this substance would be good to use to model the behavior of molten rock beneath Earth's surface. Explain your reasoning.
2. As a group, read through the procedure. Decide how you might organize your observations in a table. Design the table in your science notebook. Remember to include space for the following:
   a. Qualitative observations and labeled diagrams
   b. Observations of the heated and room-temperature Model Magma

Figure 6.3
Use a beaker clamp to pour Model Magma.

   c. Observations of Model Magma before being pushed through the soil
   d. Observations of Model Magma after being pushed through the soil
3. Pick up your group's box of materials, which consists of two containers of soil and a spoon. Place both containers of Model Magma inside the box of materials. Work inside and over the plastic box during this investigation to contain spills.
4. Look at each container of soil. Make sure the soil is firmly pressed into each container. If it is not, pack it down with the spoon.

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Investigation 6.2: Students use a model to explore how magma below Earth's surface can affect the shape of the land above it.

ELA Connection RST.6-8.3

Investigation 6.3: Students construct a model to investigate changes in Earth's surface as pressure from magma builds up in the magma changer of a volcano prior to an eruption.

By reading Building Your Knowledge: Volcano Inflation, students gain an understanding of the technology volcanologists use to monitor changes in Earth's surface to help predict eruptions.

Investigation 6.3

Volcano Monitoring

Materials

For you

- Science notebook
- Safety goggles

For your group

- 5 Toothpicks
- 1 Balloon
- 1 Index card
- 1 Piece of plastic tubing
- 1 Plastic tray
- Masking tape
- Newspaper

For your class

- Flour
- Plastic cup

Procedure

1. In this investigation, you will model how the surface of Earth changes as magma builds up in a magma chamber and a volcano erupts.
2. Use your group's materials to set up your group's model as follows:
   a. Spread newspaper over your work area.
   b. Insert one end of the tubing into the mouth of the balloon. Tape the balloon securely to the tubing by wrapping tape around the mouth of the balloon and tubing. Make sure that the tape is wrapped so that air will not escape at this connection. Refer to Figure 6.6 for an example of a completed assembly.
   c. Choose one group member who will be the person to blow air into the tubing to inflate the balloon during the investigation. This is the only person who should blow into the tubing during the investigation. Test the connection between the tubing and balloon by having them gently blow into the tubing to inflate the balloon. Make sure that the tubing and balloon are securely connected. If air is leaking from the connection between the balloon and tubing, place more tape around this connection to seal it.

Figure 6.6
Balloon taped securely to the plastic tubing
CREDIT: © Carolina Biological Supply Company

   d. Once the balloon and tubing are assembled, place the balloon in the center of the plastic tray. The end of the tubing should extend over the side of the plastic tray, as shown in Figure 6.7.
   e. Have one person from your group take the plastic tray with the balloon and tubing to the central area where your teacher has placed the flour. Make sure to hold the tray and tubing securely, so that the balloon stays in place in the center of the tray.
   f. Use the plastic cup to fill the tray three-quarters of the way full of flour, covering the balloon. Make sure that as you fill the tray with flour, you hold the tubing in place so the free end of the tube remains extended over the side of the tray and does not get covered in flour. Carefully bring the tray full of flour back to your work area.

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Investigation 6.4

Volcano Types

Materials

For you

- Science notebook

For your group

- 1 Volcano Card Set

Procedure

1. In this investigation, you will make observations to gain information about three different types of volcanoes and how their formation affects the land around them. With your group, review your notes from Getting Started, and sort your Volcano Cards into the groups you identified during Getting Started.
2. As a group, discuss the following and record your answers in your science notebook. Be prepared to share your ideas with the class.
   a. Describe the difference between magma and lava.
   b. How do you think magma and lava affect the shapes of volcanoes?
   c. Looking at the different volcano shapes you see in the cards, what evidence do you see that confirms your ideas about volcano formation?
3. Read Building Your Knowledge: *Volcano Types*. With your group, revisit your groups of volcano cards and make any changes to the sorting that you would like. You should have one group of shield volcanoes, one group of composite volcanoes, and one group of cinder cone volcanoes. List the volcanoes you put in each group in your science notebook.
4. Discuss the following questions with your group and record your answers in your science notebook:
   a. Why don't cinder cones get as big as composite volcanoes?
   b. In which volcanoes do you think the lava flows the fastest? What evidence do you see in the pictures to back up your thinking?
   c. Explain why gas bubbles in erupting magma can break it and rocks around it into pieces.

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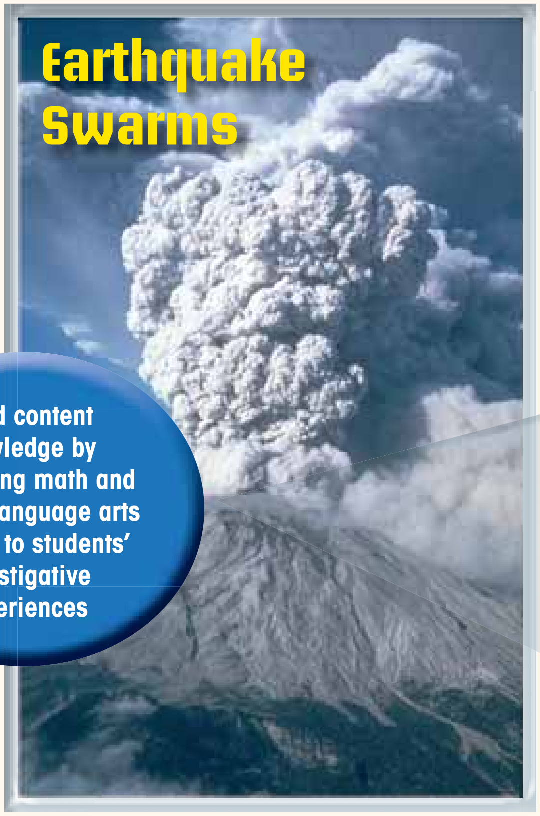
Investigation 6.4: Students gain more information about the three major types of volcanoes.

ELA Connection
SL.6-8.1

BUILDING YOUR KNOWLEDGE — READING SELECTION

Earthquake Swarms

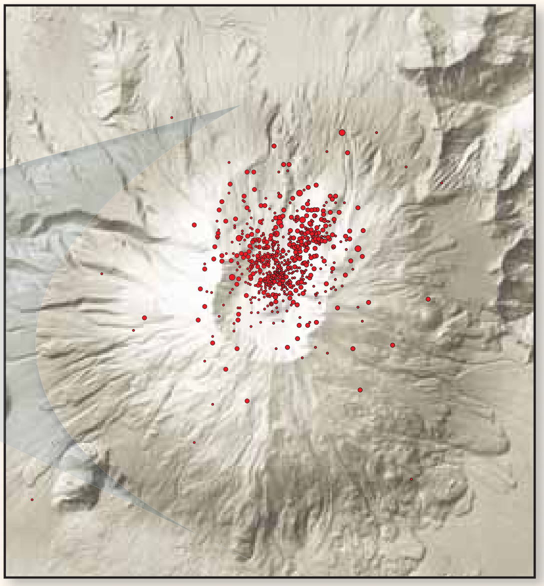


◀ Explosive eruptions of Mount St. Helens sent ash high into the atmosphere.

CREDIT: U.S. Geological Survey/photo by Mike Doukas

▼ Map of the earthquake swarm just before the eruption of Mount St. Helens

CREDIT: Adapted from U.S. Geological Survey Mount St. Helens Lidar image



Build content knowledge by connecting math and English language arts directly to students' investigative experiences

Sometimes, many earthquakes occur in a small area over a short period of time. Scientists call this kind of event an **earthquake swarm**. Two common causes of earthquake swarms are volcanic activity and slippage along faults. The earthquakes that result from volcanoes and from faults make different data patterns on seismograms. By examining the patterns, scientists can tell whether the swarms are due to volcanism or fault slippage.

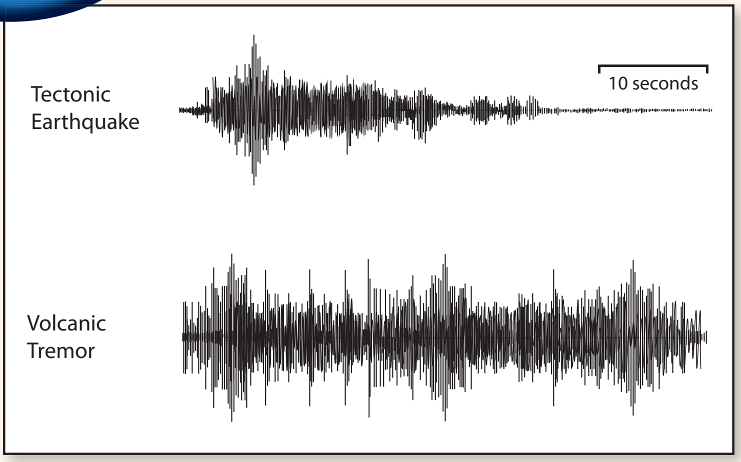
Swarms Caused by Volcanic Activity

Scientists have found that the pattern of an earthquake swarm around a volcano may show that an eruption is likely. These earthquakes are caused either by gases in the magma beneath the volcano or by the upward movement of the magma. A volcanic eruption often happens without a preceding earthquake swarm. However, an earthquake swarm is almost always followed by a volcano eruption.

Mount St. Helens is a volcano in the state of Washington. Beginning in March 1980, a network of seismic stations detected a large number of earthquakes around the volcano. Later that same month, more than 170 earthquakes were recorded in just two days! These earthquakes had magnitudes of 2.6 or greater on the Richter scale. This cluster of earthquakes is an example of a swarm.

A series of small volcanic eruptions began on March 27 of that year. These eruptions continued off and on with intense seismic activity until May 18, 1980. On that day, Mount St. Helens erupted in a massive explosion.

Math Connection MP3



Two recorded seismograms: one shows volcanic tremors and the other shows earthquakes at a fault. Notice that the data patterns look different.

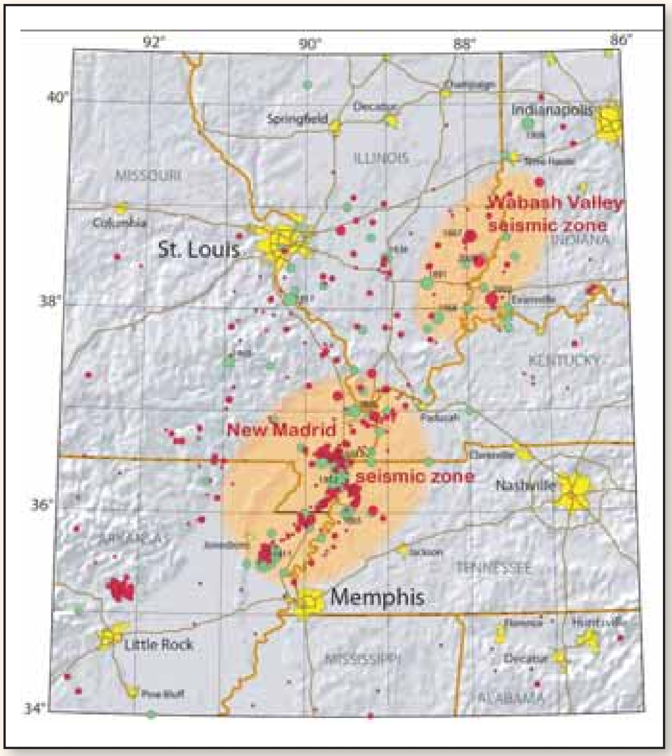
CREDIT: Weldon Washington/© Carolina Biological Supply Company

Volcanic earthquakes occur near Earth's surface. They are usually too small to feel. Small earthquakes like these are called tremors. Tremors can also occur in swarms that last for a long period of time. Some tremors happen so close together that the individual quakes are not distinguishable on a seismogram.

Swarms Caused by Movement at a Fault

New Madrid, Missouri, is a place where earthquake swarms occur along a fault. In contrast to volcanic earthquake swarms, which are shallow, these swarms begin deep inside Earth.

New Madrid, Missouri, is the most active seismic zone in the eastern United States. In 1811–1812, several major earthquakes occurred there. These quakes had an estimated magnitude of about 7.6 on the Richter scale. At the time, few people lived in the area, so the loss of life and property were not what they would be today. Even now, hundreds of earthquakes a year have epicenters near New Madrid. This is evidence that the zone is still active, so large-scale earthquakes are likely to happen there again. ■



This map shows an earthquake swarm around the town of New Madrid, Missouri. These earthquakes are caused by movement at a fault.

CREDIT: U.S. Geological Survey

Three-Dimensional Application

Reflecting on What You've Done: Students review what they've learned in Lesson 6 about volcano types and how lava influences the type and shape of a volcano, and use this information to devise a strategy to determine whether a volcano is active.

Lesson 6 Volcanoes: Building Up

Reflecting On What You've Done

1. Tell students to find the page in their science notebooks where they wrote down their initial observations of similarities among volcanoes featured in the Volcano Card Set. Allow time for students to review their initial thoughts with their group and discuss what they have learned about characteristics and types of volcanoes. They should record their reflections in their science notebooks.

2. Have students read Extending Your Knowledge: *Volcanoes: Help or Hindrance?* and answer the questions in the Student Guide in their science notebooks.

3. Instruct groups to choose one of the volcanoes from the card set, or another volcano of their choosing, and discuss answers to the questions in the Student Guide. They should record their responses in their science notebooks.

- **a.** Most volcanoes will be on a subduction fault, though some may be on hot spots.
- **b.** Answers will vary. Shield volcanoes have more-viscous magma that flows more slowly than lava from composite volcanoes.
- **c.** Answers will vary.

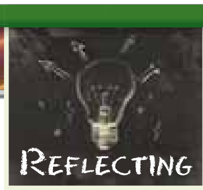
4. Have students read Extending Your Knowledge: *Reading the Signs: Detecting Seismic Events* and answer the questions that follow the reading selection in their science notebooks.

5. Tell groups to act as geologists who need to determine whether a particular volcano is still active. Instruct them to come up with a strategy for how they would set up their research and to record their ideas in their science notebooks. Hold a class discussion on the approaches of different groups. Their responses should include the use of technology such as tiltmeters, GPS monitoring stations, cameras, observations of the physical structure of the mountain, and so forth.

EXIT SLIP

Volcanoes are formed as magma pushes up from beneath the surface of Earth, builds up pressure against the surface, and eventually explodes up out of the ground. Both the amount of magma and the pressure it exerts on Earth's surface build up over time. The magma that explodes out and flows across Earth's surface as lava also builds up a volcano. There are three types of volcanoes, characterized by shape and composition: shield, cinder cone, and composite.

ELA Connection WHST.6-12.9



ON WHAT YOU'VE DONE

1. Think back to the beginning of the lesson, when you first sorted the volcano cards. Find the page in your science notebook where you wrote down similarities between the volcanoes in the pictures and why you grouped them as you did. With your group, review your initial thoughts. What new insights have you gained that you could add to the list of characteristics? How can you now use those insights to help you determine volcano type? Make a list of these in your science notebook.
2. Read Extending Your Knowledge: *Volcanoes: Help or Hindrance?* and answer the questions at the end of the reading selection in your science notebook.
3. Choose one of the volcanoes from the volcano cards, or choose another volcano you know of. Discuss these questions with your group and record your responses in your science notebook:
   - **a.** What type of fault do you think the volcano you selected is sitting on?
   - **b.** How might the shape of the volcano relate to the flow rate of the lava coming out of it?
   - **c.** **Viscosity** is a property that describes the tendency of a liquid to resist flowing. What characteristics of the lava do you imagine might affect its viscosity? How might this affect the shape of the volcano?
4. Read Extending Your Knowledge: *Reading the Signs: Detecting Seismic Events* and record the answers to the questions at the end of the reading selection in your science notebook.
5. Imagine that your group is tasked with determining whether a particular mountain is an active volcano. Discuss how you would set up your research, and record your ideas in your science notebook. Be prepared to share your ideas with the class.
6. Read Extending Your Knowledge: *An Island Is Born* and record your answers to the questions at the end of the reading selection in your science notebook.
7. Open your science notebook to the page with your concept map. With your group, discuss what you would add or change to the concept map, given what you have learned, and make a list of changes.

EXIT SLIP

How are volcanoes formed?

Exit slips check for understanding and the ability to explain phenomena

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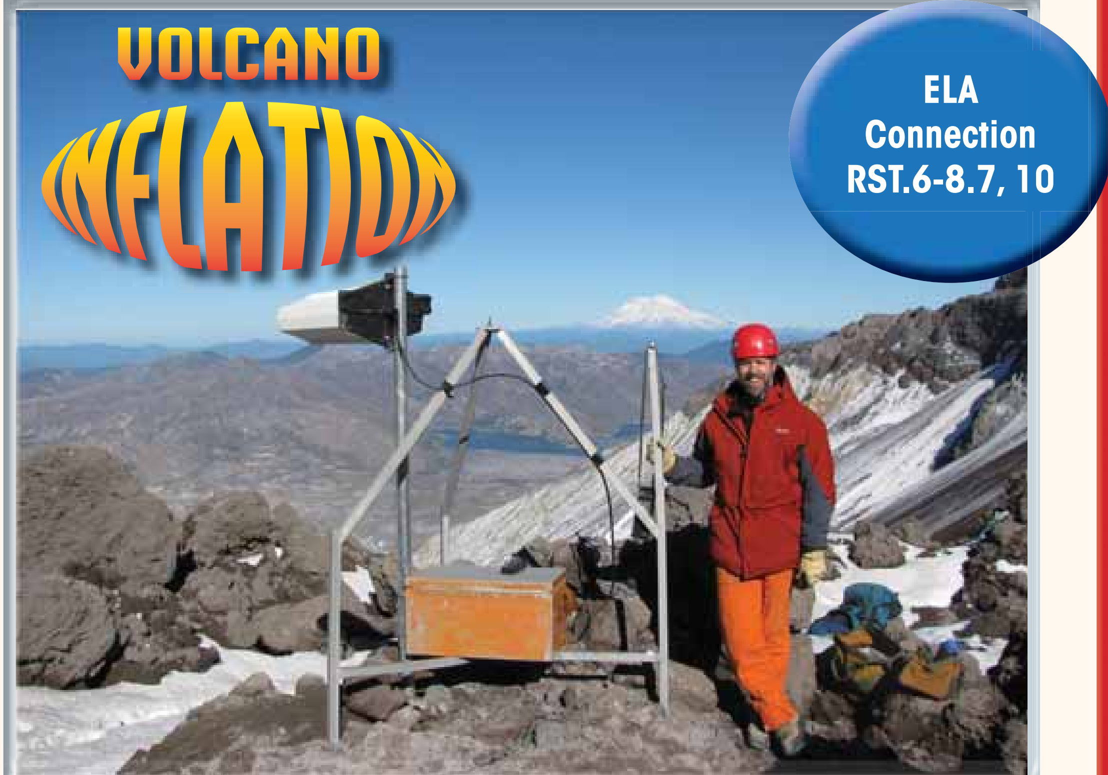
166 STCMS™ / Earth's Dynamic Systems

Non-Fiction Literacy with Real-World Applications

Non-fiction literacy features real-world phenomena and applications connected to students' investigative learning experiences.

BUILDING YOUR KNOWLEDGE READING SELECTION



Scientists from the U.S. Geological Survey deploy a portable instrument called a "spider" to monitor Mount St. Helens. The spider has a seismometer and GPS to monitor the volcano. This device will send data to an observatory.

CREDIT: U.S. Geological Survey/photo by Adam Mosbrucker

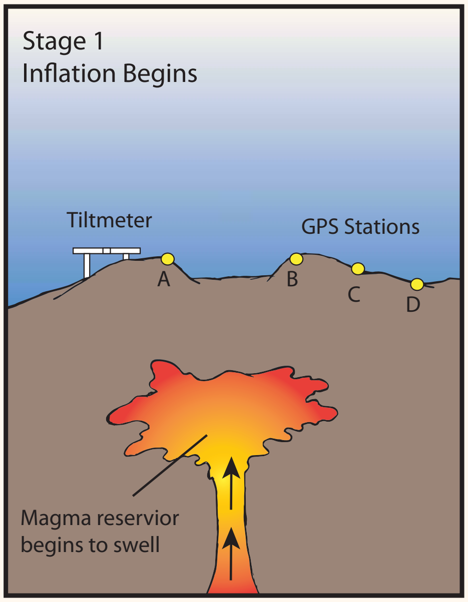
Four changes happen near a volcano when it is about to erupt. One of the most important is **volcano inflation**, when the flanks or sides of the volcano swell. Volcano inflation, also called uplift, signals the arrival of new magma under the volcano. When this happens along with increased earthquakes, higher ground temperatures, and a change in volcanic gases, scientists will warn others that an eruption may happen soon. This early warning allows people to leave the area while it is still safe and avoid being hurt.

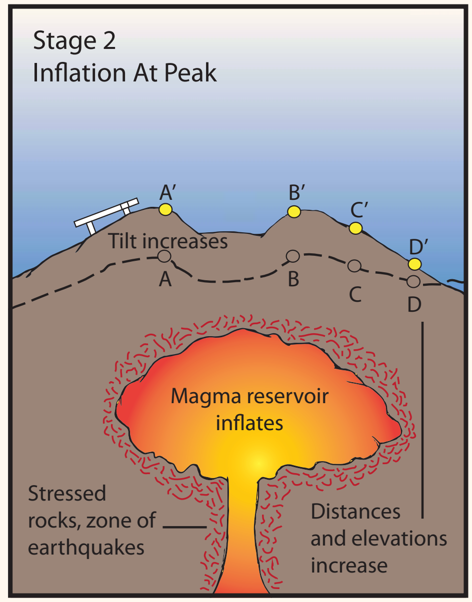
Many volcanoes in the world have volcano observatories. Scientists place seismometers and other equipment on and around the volcano. Data from the seismometers travel by radio to the observatory. Volcanologists at the observatory then study the data to track changes happening beneath the volcano.

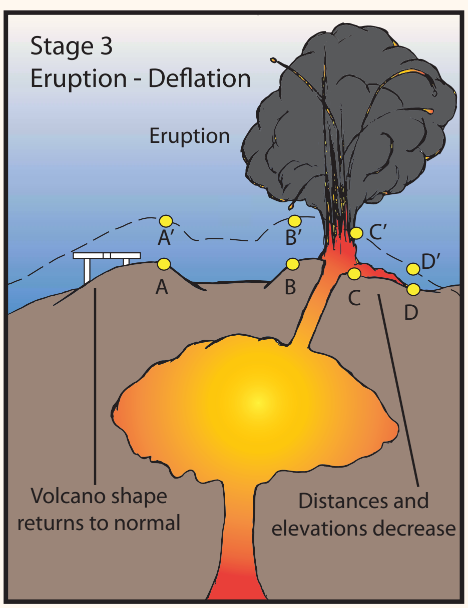
Detecting Volcano Inflation

A greater-than-usual number of earthquakes may be the first clue that an eruption is near. However, volcano inflation is an even stronger indicator. To detect volcano inflation, scientists use a **tiltmeter**. Tiltmeters are placed on the

continued







When a volcano inflates, the force of the rising magma pushes up the surface above it. When a volcano erupts, magma may flow. When the eruption ends, the ground may subside or sink.

CREDIT: Adapted from U.S. Geological Survey Simplified Inflation-Deflation Cycle

volcano. Like seismometers, tiltmeters send their data to the observatory by radio. As the magma moves up into the volcano, the ground around the volcano tilts away from the top. Tiltmeters detect even tiny changes in the angle of the ground and send this data to the observatory.

Scientists also set up stations with global positioning systems (GPS) on the volcano to monitor ground changes on a bigger scale. When magma nears the surface, it can cause the volcano to swell. It can also cause other areas to subside or sink, and cracks could open in the rock. The GPS sends data to the observatory about how much the surface moved and in what direction. At the observatory, volcanologists watch for changes in the patterns of the GPS data to learn more about where the magma is and what it is doing. Often, changes in data patterns will indicate that geoscience processes have changed Earth's surface over time.

Detecting Other Changes

Before some volcanic eruptions, the gases coming out of the ground have an increased amount of sulfur dioxide. This can indicate that the magma is near the surface. Higher ground temperatures also may signal an impending eruption. These data can be measured by satellites and transmitted to the volcano observatory.

Advance Warning

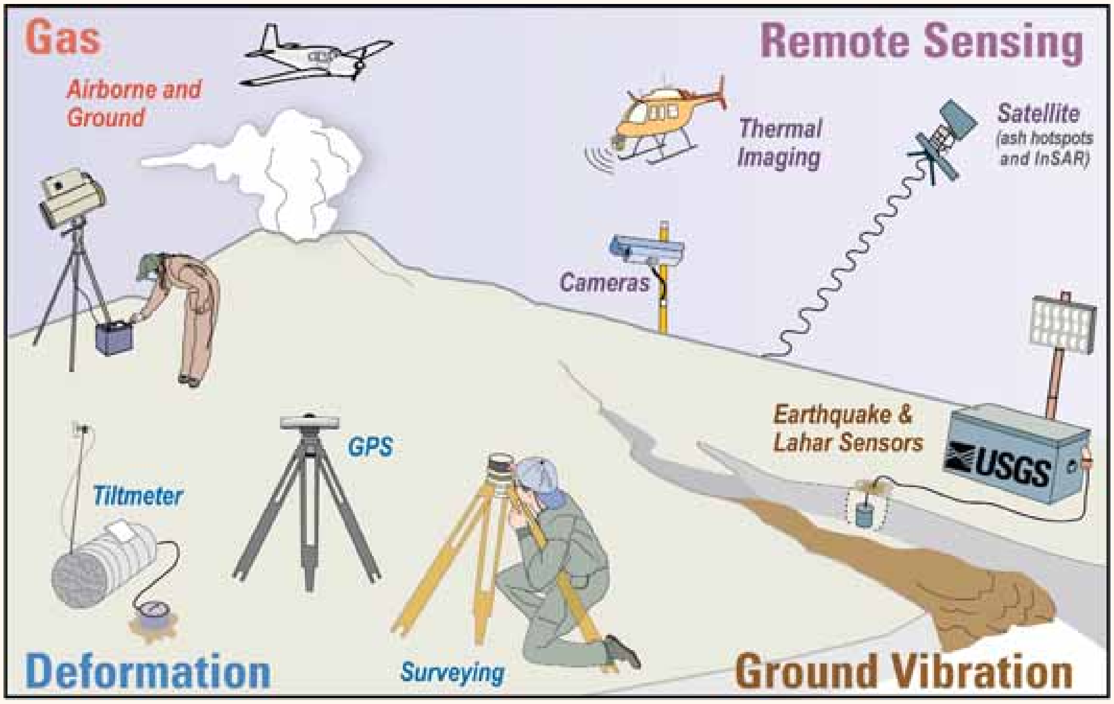
Devices that are placed once and monitored from a distance let scientists observe a volcano without risking their safety. Before volcanologists can identify changes in data patterns, however, they have to collect data for a long time when the volcano is in a resting state. That way, they know what is typical for the volcano. With this baseline data, volcanologists can then detect changes—and possibly identify an eruption well before it happens. Then, people can be warned and can move to a safer place. ■

▲ This GPS station is a remote-sensing device that records changes in elevation or other ground movement around a volcano.

CREDIT: U.S. Geological Survey/photo by Liz Westby

▼ Scientists use many instruments to monitor volcanic activity and collect data.

CREDIT: U.S. Geological Survey/illustration by Lisa Faust



Summative Assessment

STCMS summative assessments target the full range of unit concepts and practices through a performance assessment and a written assessment.

Lesson 12: Assessment: *Earth's Dynamic Systems*: Students apply the knowledge and skills they have developed over the course of the unit to produce a geodynamic event preparedness plan.

ELA and Math Connections
WHST.6-8.1b, 7, 9
MP2

Lesson 12 Assessment: Earth's Dynamic Systems

FOCUS QUESTION How can we use knowledge of Earth's dynamic systems to understand the past and prepare for the future?

Introduction

In this unit, you have explored how geologic processes affect the surface of our planet and how we can use evidence to describe Earth's history and predict its future. Some of the key topics you studied include plate tectonics, geoscience processes, matter cycling, and the fossil record.

The performance assessment in this lesson focuses on geodynamic events: earthquakes and volcanic eruptions. You and your group will be assigned a particular geographic region. You will research past geodynamic events in your region and prepare and present proposals to mitigate their effects. You will draw on your skills and knowledge to determine how much funding each proposal should receive. You will also answer written questions about Earth's dynamic systems to further demonstrate what you have learned throughout this unit.

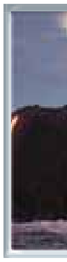


Figure 12.1
The volcan
2014, a la
What actic
mitigate it
CREDIT: thearti

Objectives for This Lesson

- Review concepts from the *Earth's Dynamic Systems* u
- Complete a Performance Assessment by obtaining, e about geodynamic event preparedness.
- Make a recommendation about allocating funds for evidence and scientific reasoning.
- Apply your knowledge and skills to answer questions related to Earth's dynamic systems.
- Update your concept map with your new knowledge daily life.

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Performance Assessment

Geodynamic Event Preparedness

Materials

For you
- Science notebook

For your group
- 1 Lesson Master 12.PAa: *Geodynamic Event Research Scoring Rubric*
- Materials to make a visual aid

For your class
- Access to resources

Procedure

1. You have learned a lot about Earth's dynamic systems. In this investigation, you will work with your group to analyze and interpret data on geodynamic events and use the data you collect to prepare a proposal for geodynamic event preparedness. Your teacher will assign your group a particular geographic region, and your proposal will be specific to the needs of that area. Record the region you are assigned in your science notebook.
2. You will need to collect data about significant geodynamic events that have occurred in your region. Using the data you collect, you will determine:
   a. Areas that are susceptible to geodynamic events
   b. Areas of highest and lowest risk for severe events
   c. Areas of the highest and lowest event frequency
   d. Types of damage typically caused by geodynamic events
   e. Any phenomena typically observed before or after a geodynamic event

Figure 12.2
A wide variety of instruments are available for monitoring geodynamic events. Their use is driven by individual and societal needs, desires, and values. What technologies would you use and where would you use them?
CREDIT: U.S. Geological Survey

3. You will use at least four appropriate sources for your research. At the end of the Performance Assessment, your group will turn in a bibliography of all the sources your group used.
4. Your work will be evaluated using Lesson Master 12.PAa: *Geodynamic Event Research Scoring Rubric*. Discuss the rubric as a class, and ask any questions you may have during the discussion.

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How Are They Progressing Against the Next Generation Science Standards?

Unit-specific rubrics to assess three-dimensional learning guide evaluation of student proficiency with the Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas addressed in the specific unit.

Appendix F: Assessing Three-Dimensional Learning

Science and Engineering Practices			
Criterion	1. Beginning	2. Developing	3. Proficient
Asking Questions and Defining Problems	Student cannot ask questions that can be investigated using available facilities and resources.	Student can partially ask questions that can be investigated using available facilities and resources.	Student can ask questions that can be investigated using available facilities and resources.
	Student ca... hypothese... on observa... principles.		
	Student ca... problem th... through th... an object, ... system.		
	Student ca... multiple cr... constraints... possible sc...		
Developing and Using Models	Student ca... model to p...		
	Student ca... a model to... unobserva...		
	Student ca... and use a ... phenomen...		
	Student ca... model to g... ideas abou... including t... inputs and...		

Crosscutting Concepts			
Criterion	1. Beginning	2. Developing	3. Proficient
Patterns	Student rarely observes how patterns of forms and events guide organization and classification while prompting questions about relationships and the factors that influence them.	Student occasionally observes how patterns of forms and events guide organization and classification while prompting questions about relationships and the factors that influence them.	Student frequently observes how patterns of forms and events guide organization and classification while prompting questions about relationships and the factors that influence them.
	Student rarely uses graphs and charts to identify patterns in data.	Student occasionally uses graphs and charts to identify patterns in data.	Student frequently uses graphs and charts to identify patterns in data.
	Student rarely uses patte... to identify cause-and-eff... relationships.		
	Student rarely observes t... patterns in rates of chan... other numerical relation... can provide information... natural systems.		
Cause and Effect	Student rarely uses caus... effect relationships to pr... phenomena in natural o... designed systems.		
	Student rarely understan... that phenomena may ha... more than one cause.		
	Student rarely understan... that some cause-and-eff... relationships in systems ... only be described using probability.		
Scale, Proportion, and Quantity	Student rarely explains t... time, space, and energy phenomena can be obse... at various scales using m... to study systems that are... large or too small.		
	Student rarely explains t... proportional relationship... among different types o... quantities provide inform... about magnitude, prope... and processes.		

Disciplinary Core Ideas			
Criterion	1. Beginning	2. Developing	3. Proficient
ESS1.C: The History of Planet Earth	Student cannot explain that the geologic timescale interpreted from rock strata provides a way to organize Earth's history.	Student can partially explain that the geologic timescale interpreted from rock strata provides a way to organize Earth's history.	Student can explain that the geologic timescale interpreted from rock strata provides a way to organize Earth's history.
	Student cannot explain that analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.	Student can partially explain that analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.	Student can explain that analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.
	Student cannot explain that tectonic processes continually generate new ocean seafloor at ridges.	Student can partially explain that tectonic processes continually generate new ocean seafloor at ridges.	Student can explain that tectonic processes continually generate new ocean seafloor at ridges.
	Student cannot explain that tectonic processes continually destroy old seafloor at trenches.	Student can partially explain that tectonic processes continually destroy old seafloor at trenches.	Student can explain that tectonic processes continually destroy old seafloor at trenches.
ESS2.A: Earth Materials and Systems	Student cannot explain that all Earth's systems interact over scales that range from microscopic to global in size.	Student can partially explain that all Earth's systems interact over scales that range from microscopic to global in size.	Student can explain that all Earth's systems interact over special scales that range from microscopic to global in size.
	Student cannot explain that all Earth's systems operate over timescales that range from fractions of a second to billions of years.	Student can partially explain that all Earth's systems operate over timescales that range from fractions of a second to billions of years.	Student can explain that all Earth's systems operate over timescales that range from fractions of a second to billions of years.
	Student cannot explain that all Earth's processes are the result of energy flowing and matter cycling within and among the planet's systems.	Student can partially explain that all Earth's processes are the result of energy flowing and matter cycling within and among the planet's systems.	Student can explain that all Earth's processes are the result of energy flowing and matter cycling within and among the planet's systems.
	Student cannot explain that the energy for Earth's processes is derived from the Sun and Earth's hot interior.	Student can partially explain that the energy for Earth's processes is derived from the Sun and Earth's hot interior.	Student can explain that the energy for Earth's processes is derived from the Sun and Earth's hot interior.
	Student cannot explain that the energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living things.	Student can partially explain that the energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living things.	Student can explain that the energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living things.

Is It Really an NGSS Program?

7-Point NGSS Program Checklist—A Quick-Start Guide

Five Innovations of NGSS	Questions
Three-Dimensional Construction	• Does the curriculum explicitly reflect and integrate all three dimensions of the NGSS and build to the Performance Expectations? • Are there multiple opportunities for students to master each dimension?
Focus on Engaging Phenomena	• Are students observing, investigating, modeling, and explaining phenomena? • Are they conducting inquiry science investigations and designing solutions? • Are they engaging?
Engineering Design and the Nature of Science	• Are engineering standards and science standards taught with equal importance? • Do learning experiences include Disciplinary Core Ideas of engineering design as well as the Science and Engineering Practices and Crosscutting Concepts of both engineering and the nature of science? • Are engineering design and the nature of science integrated throughout the science content and not separate lessons at the unit's end?
Coherent Learning Progression	• Is it clear that there is a coherent learning progression within each unit as well as across grade levels? • Is there a convincing concept storyline or other coherent framework? • Do units build on and extend knowledge and understanding gained in prior grades?
Connections to Math and ELA	• Are connections to the Mathematics and ELA Standards explicit?
Key Support Materials	
Materials	• Do students have the materials to carry out scientific investigations and engineering design projects?
Assessment	• Are there multiple assessments capable of evaluating student progress and the performance expectations, including the science and engineering practices?

So many programs claim to meet the NGSS, but how can you be sure? Use this 7-point NGSS program checklist as a guide.

STCMS™	Where Is It in STCMS?
Yes	• Unit Overview lesson summaries show how Performance Expectations build over time • Alignment to Next Generation Science Standards before each lesson explicitly describes the integration of the Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices • Lessons that integrate real-world situations with scientific principles, leading to engaging and relevant instruction

Yes	• Focus Questions for each lesson that look at phenomena from a science perspective
	• Introductions that provide students with examples of phenomena that they can relate to
	• Investigations that:
	  • give students multiple opportunities to study, model, and explain phenomena
	  • provoke questions and call for the design of solutions

Yes	• Lesson at a Glance Alignment to Next Generation Science Standards • Lessons build an understanding of science and the world while incorporating meaningful engineering design opportunities • Lessons build an understanding of science content and develop use of evidence to revise design solutions
Yes	• Unit Concept Storylines show at a glance the conceptual progression over the course of the unit • Unit Table of Contents shows the focus on investigations and phenomena and on nonfiction support • STCMS Learning Framework illustrates the progression of concepts across grade levels and strands • Lessons that provide multiple opportunities for students to engage prior knowledge and experience investigative phenomena to deepen understanding and provide explanations
Yes	• Lesson at a Glance correlates ELA and Mathematics Standards for each lesson • Reading Selections that include discussion questions intentionally constructed to support ELA Standards • Teacher Edition includes explicit guidance on the importance of and the "how to" of connecting science and the Mathematics and ELA standards (Tab 3)
Yes	• Unit purchase includes the Teacher Edition, Student Editions—both with digital access—and all the materials to complete the investigations that are not commonly found in middle school science labs/classrooms.

Yes	• A coherent system of classroom-based assessments that provide powerful information to inform teaching and learning, for not only the teacher, but the student as well. STCMS units include:
	  • pre-assessment lesson
	  • formative assessment including Exit Slips to monitor student progress
	  • self-assessment for students
	  • summative assessment—performance and written components
	  • unit-specific NGSS rubrics to assess three-dimensional learning

Smithsonian | STC Science and Technology Concepts™ Middle School

Learning Framework

Units for Grades 6—8

Physical Science	Life Science	Earth/Space Science
Energy, Forces, and Motion PS2-1, PS2-2, PS2-3, PS2-5, PS3-1, PS3-2, PS3-5, ETS1-1, ETS1-2, ETS1-3, ETS1-4	**Ecosystems and Their Interactions** LS1-5, LS1-6, LS2-1, LS2-2, LS2-3, LS2-4, LS2-5, LS4-4, LS4-6, ESS3-3, ETS1-1, ETS1-2	**Weather and Climate Systems** ESS2-4, ESS2-5, ESS2-6, ESS3-2, ESS3-4, ESS3-5, PS3-4, ETS1-1, ETS1-2
Matter and Its Interactions PS1-1, PS1-2, PS1-3, PS1-4, PS1-5, PS1-6, PS3-4, ETS1-1, ETS1-2, ETS1-3, ETS1-4	**Structure and Function** LS1-1, LS1-2, LS1-3, LS1-6, LS1-7, LS1-8, LS4-2, LS4-3	**Earth's Dynamic Systems** LS4-1, ESS1-4, ESS2-1, ESS2-2, ESS2-3, ESS3-1,ESS3-2, ETS1-1, ETS1-2, ETS1-3, ETS1-4
Electricity, Waves, and Information Transfer LS1-8, PS2-3, PS2-5, PS3-3, PS3-4, PS3-5, PS4-1, PS4-2, PS4-3, ETS1-1, ETS1-2, ETS1-3, ETS1-4	**Genes and Molecular Machines** LS1-1, LS1-4, LS3-1, LS3-2, LS4-4, LS4-5, LS4-6	**Space Systems Exploration** PS2-4, ESS1-1, ESS1-2, ESS1-3, ETS1-1, ETS1-2

Three-dimensional learning for middle school

For more information, contact Curriculum@carolina.com